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SPECIFICATION

INVENTION: **MODIFIED PRINTED DIPOLE ANTENNAS FOR WIRELESS MULTI-BAND COMMUNICATION SYSTEMS**

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BACKGROUND AND SUMMARY OF THE DISCLOSURE

[0001] The present disclosure relates to an antenna for wireless communication devices and systems and, more specifically, to printed dipole antennas for communication for wireless multi-band communication systems.

[0002] Wireless communication devices and systems are generally hand held or are part of portable laptop computers. Thus, the antenna must be of very small dimensions in order to fit the appropriate device. The system is used for general communication, as well as for wireless local area network (WLAN) systems. Dipole antennas have been used in these systems because they are small and can be tuned to the appropriate frequency. The shape of the printed dipole is generally a narrow, rectangular strip with a width less than 0.05 $\lambda 0$ and a total length less than 0.5 $\lambda 0$. The theoretical gain of the isotrope dipole is generally 2.5 dB and for a double dipole is less than or equal to 3 dB. One popular printed dipole antenna is the planar inverted-F antenna (PIFA).

[0003] The present disclosure is a dipole antenna for a wireless communication device. It includes a first conductive element superimposed on a portion of and separated from a second conductive element by a first dielectric layer. A first conductive via connects the first and second conductive elements through the first dielectric layer. The second conductive element is generally U-shaped. The second conductive element includes a plurality of spaced conductive strips extending transverse from adjacent ends of the legs of the U-shape. Each strip is dimensioned for a different center frequency $\lambda 0$. The first conductive element may be L-shaped and one of the legs of the L-shape being superimposed on one of the legs of the U-shape. The first conductive via connects the other leg of the L-shape to the other leg of the U-shape.

[0004] The first and second conductive elements are each planar. The strips have a width of less than 0.05 $\lambda 0$ and a length of less than 0.5 $\lambda 0$.

[0005] The antenna may be omni-directional or uni-dimensional. If it is uni-dimensional, it includes a ground plane conductor superimposed and separated from the second conductive element by a second dielectric layer. A third conductive element is superimposed and separated from the strips of the second conductive element by the first dielectric layer. A second conductive via connects the third conductive element to the ground conductor through the dielectric layers.

The first and third conductive elements may be co-planar. The third conductive element includes a plurality of fingers superimposed on a portion of lateral edges of each of the strips.

[0006] These and other aspects of the present disclosure will become apparent from the following detailed description of the disclosure, when considered in conjunction with accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0007] Figure 1 is a perspective, diagrammatic view of an omni-directional, quad-band dipole antenna incorporating the principles of the present invention.

[0008] Figure 2A is a plane view of the dipole conductive layers of Figure 1.

[0009] Figure 2B is a six-band modification of the dipole conductive layer of Figure 2A.

[00010] Figure 3 is a plane view of the antenna of Figure 1.

[00011] Figure 4 is a directional diagram of the antenna of Figure 1.

[00012] Figure 5 is a graph of the directional gain of two of the tuned frequencies.

[00013] Figure 6 is a graph of the frequency versus voltage standing wave ratio (VSWR) and the gain of S11.

[00014] Figure 7A is a graph showing the effects of changing the feed point or via on the characteristics of the dipole antenna of Figure 1, as illustrated in Figure 7B.

[00015] Figure 8 is a graph showing the effects of changing the width of the slot S of the dipole of Figure 1.

[00016] Figure 9 is a graph showing the effects for a 2-, 3- and 4-strip dipole of Figure 1.

[00017] Figure 10A is a graph showing the effects of changing the width of the dipole of Figure 1, as illustrated in Figure 10B.

[00018] Figure 11 is a perspective, diagrammatic view of a directional dipole antenna incorporating the principles of the present invention.

[00019] Figure 12 is a plane top view of the antenna of Figure 11.

[00020] Figure 13 is a bottom view of the antenna of Figure 11.

[00021] Figure 14 is a graph of the directional gain of the antenna of Figure 11 for five frequencies.

[00022] Figure 15 is a graph of frequency versus VSWR and S11 of the antenna of Figure 11.

[00023] Figure 16A is a graph showing the effects of changing the feed point or via 40 for the feed positions illustrated in Figure 16B for the dipole antenna of Figure 11.

[00024] Figure 17 is a graph showing the effects of changing the width of slot S for the dipole antenna of Figure 11.

[00025] Figure 18A is a graph showing the effects of changing the width of the dipole, as illustrated in Figure 18B, of the antenna of Figure 11.

[00026] Figure 19A is a graph of the second frequency showing the effect of changing the length of the directive dipole, as illustrated in Figure 19B, of the dipole antenna of Figure 11.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[00027] Although the present antenna of a system will be described with respect to WLAN dual frequency bands of, e.g., approximately 2.4 GHz and 5.2 GHz, the present antenna can be designed for operation in any of the frequency bands for portable, wireless communication devices. These could include GPS (1575 MHz), cellular telephones (824-970 MHz and 860-890 MHz), some PCS devices (1710-1810 MHz, 1750-1870 MHz and 1850-1990 MHz), cordless telephones (902-928 MHz) or Blue Tooth Specification 2.4-2.5 GHS frequency ranges.

[00028] The antenna system 10 of Figures 1, 2A and 3 includes a dielectric substrate 12 with cover layers 14, 16. Printed on the substrate 12 is a first conductive layer 20, which is a micro-strip line, and on the opposite side is a split dipole conductive layer 30. The first conductive layer 20 is generally L-shaped having legs 22, 24. The second conductive layer 30 includes a generally U-shaped strip balloon line portion 32 having a bight 31 and a pair of separated legs 33. Extending transverse and adjacent the ends of the legs 33 are a plurality of strips 35, 37, 34, 36. Leg 22 of the first conductive layer 20 is superimposed upon one of the legs 33 of the second conductive layer 30 with the other leg 24 extending transverse a pair of legs 33. A conductive via 40 connects the end of leg 24 to one of the legs 33 through the dielectric substrate 12. Terminal 26 at the other end of leg 22 of the first conductive layer 20 receives the drive for the antenna 10.

[00029] The four strips 34, 36, 35 and 37 are each uniquely dimensioned so as to be tuned to or receive different frequency signals. They are each dimensioned such that the strip has a width less than 0.05 $\lambda 0$ and a total length of less than 0.5 $\lambda 0$.

[00030] Figure 2B shows a modification of Figure 2A, including six strips 35, 37, 39, 34, 36, 38 each extending from an adjacent end of the legs 33 of the second conductive layer 30. This allows tuning and reception to six different frequency bands. The strips of both embodiments are generally parallel to each other.

[00031] The dielectric substrate 12 may be a printed circuit board, a fiberglass or a flexible film substrate made of polyimide. Covers 14, 16 may be additional, applied dielectric layers or may be hollow casing structures. Preferably, the conductive layers 20, 30 are printed on the dielectric substrate 12.

[00032] As an example of the quad-band dipole antenna of Figure 1, the frequencies may be in the range of, for example, 2.4-2.487, 5.15-5.25, 2.25-5.35 and 5.74-5.825 GHz. For the directional diagram of Figure 4, the directional gain is illustrated in Figure 5 for two of the frequencies 2.4 GHz (Graph A) and 5.6 GHz (Graph B). A maximal gain at 90 degrees is 5.45 dB at 2.4 GHz and 6.19 dB at 5.6 GHz. VSWR and the magnitude S11 are illustrated in Figure 6. VSWR is below 2 at the 2.4 GHz and the 5.6 GHz frequency bands. The bands from 5.15-5.827 merge at the 5.6 GHz frequency.

[00033] The height h of the dielectric substrate 12 will vary depending upon the permeability or dielectric constant of the layer.

[00034] The narrow, rectangular strips 34, 36, 35, 37 of the appropriate dimension increases the total gain by reducing the surface waves and loss in the conductive layer. The number of conductive strips also effects the frequency sub-band.

[00035] The position of the via 40 and the slot S between the legs 33 of the U-shaped sub-conductor 32 effect the antenna performance related to the gain "distributions" in the frequency bands. A width of slot dimensions S and the location of the via 40 are selected so as to have approximately the same gain in all of the frequency bands of the strips 34, 36, 35, 37. The maximum theoretical gain obtained are above 4 dB and are 5.7 dB at 2.4 GHz and 7.5 dB at 5.4 GHz.

[00036] Figure 7A is a graph for the various positions of the feed point fp or via 40 and the effect on VSWR and S11. The center feed point fp1 corresponds to the results of Figure 6. Although the change of the feed point fp has a small effect in gain, it has a greater effect in shifting the $\lambda 0$ at the second frequency band in the 5 GHz range.

[00037] Figure 8 shows the effect of changing the slot width from 1 mm to 3 mm to 5 mm. The 3 mm slot width corresponds to Figure 6. Although there is not much change in the VSWR, there is substantial change in the gain at S11. For example, for the 5 mm strip, S11 is -21 dB at 2.5 GHz and -16 dB at 5.3 GHz. For the 3.3 mm strip, S11 is -14 dB at 2.5 GHz and -25 dB at 5.23 GHz. For the 1 mm strip, S11 is approximately equal to -13 dB at 2.5 GHz and at 5.3 GHz.

[00038] It should be noted that changing the length of legs 34, 35, 36, 37 between 5 mm, 10 mm and 15 mm has very little effect on VSWR and the gain at S11. Figure 6 corresponds to a 15 mm length. Also, changing the distance between the legs 34, 35, 36, 37 to between 1 mm, 2 mm and 4 mm also has very little effect on VSWR and the gain at S11. Two millimeters of separation is reflected in Figure 6. The difference in gain between the 2 mm and the 4 mm spacing was approximately 2 dB. Figure 9 shows the response of 2, 3 and 4 dipole strips.

[00039] Figures 10A and 10B show the effect of changing the width of the dipole while maintaining the width of the individual strips. The width of the dipole varies from 6 mm, 8 mm to 10 mm. The 6 mm width corresponds to that of Figure 6. For the 6 mm width, there are two distinct frequency bands at 2.4 having an S11 gain of -14 dB and at 5.3 GHz having an S11 gain of -25 dB. For the 8 mm width, there is one large band having a VSWR below two extending from 1.74 to 5.4 GHz and having an S11 gain of approximately 20 dB. Similarly, the 10 mm width is one large band at a VSWR below two extending from 1.65 to 5.16 GHz and having a gain at 2.2 GHz of -34 dB to a gain at 4.9 GHz of -11 dB.

[00040] A directional or uni-directional dipole antenna incorporating the principles of the present invention is illustrated in Figures 7 through 9. Those elements having the same structure, function and purpose as that of the omni-directional antenna of Figure 1 have the same numbers.

[00041] The antenna 11 of Figures 11 through 13 includes, in addition to the first conductive layer 20 on a first surface of the dielectric substrate 12 and a second conductive dipole 30 on the opposite surface of the dielectric substrate 12, a ground conductive layer 60 separated from the second conductive layer 30 by the lower dielectric layer 16. Also, a third conductive element 50 is provided on the same surface of the dielectric substrate 12 as the first conductive element 20. The third conductive element 50 is a directive dipole. It includes a center strip 51

having a pair of end portions 53. This is generally a barbell-shaped conductive element. It is superimposed over the strips 34, 36, 35, 37 of the second conductive layer 30. It is connected to the ground layer 60 by a via 42 extending through the dielectric substrate 12 and dielectric layer 16.

[00042] The directive dipole 50 includes a plurality of fingers superimposed on a portion of the edges of each of the strips 34, 36, 35, 37. As illustrated, the end strips 52, 58 are superimposed and extend laterally beyond the lateral edges of strips 34, 36, 35, 37. The inner fingers 54, 56 are adjacent to the inner edge of strips 34, 36, 35, 37 and do not extend laterally therebeyond.

[00043] Preferably, the permeability or dielectric constant of the dielectric substrate 12 is greater than the permeability or dielectric constant of the dielectric layer 16. Also, the thickness h1 of the dielectric substrate 12 is substantially less than the thickness h2 of the dielectric layer 16. Preferably, the dielectric substrate 12 is at least half of the thickness of the dielectric layer 16.

[00044] The polygonal perimeter of the end portion 53 of the dipole directive 50 has a similar shape of the PEAN03 fractal shape directive dipole. It should also be noted that the profile of the antenna 12 gives the appearance of a double planar inverted-F antenna (PIFA).

[00045] Figure 14 is a graph of the directional gain of antenna 12, while Figure 15 shows a graph for the VSWR and the gain S11. Five frequencies are illustrated in Figure 10. The maximum gain are above 7 dB and are 8.29 dB at 2.5 GHz and 10.5 dB at 5.7 GHz. The VSWR in Figure 15 is for at least two frequency bands that are below 2.

[00046] Figures 16A and 16B show the effect of the feed point fp or via 40. Feed point zero is similar to that shown in Figure 15. Figure 17 shows the effect of the slot width S for 1 mm, 3 mm and 5 mm. The 3 mm width corresponds generally to that of Figure 15. Figures 18A and 18B show the effect of the dipole strip width SW for widths of 6 mm, 8 mm and 10 mm. The 6 mm width corresponds to that of Figure 15. Figures 19A and 19B show the effect of the length SDL of portion 51 of the directive dipole 50 on the second frequency in the 5 GHz range. The 8 mm width corresponds generally to that of Figure 15.

[00047] Although not shown, a number of via holes around the dipole through the insulated layer 12 may be provided. These via holes would provide pseudo-

photonic crystals. This would increase the total gain by reducing the surface waves and the radiation in the dielectric material. This is true of both antennas.

[00048] Although the present disclosure has been described and illustrated in detail, it is to be clearly understood that this is done by way of illustration and example only and is not to be taken by way of limitation. The scope of the present disclosure is to be limited only by the terms of the appended claims.